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Phototactic Insects: Seasonal Abundance and Diversity in Built Environments in Awka, Anambra State, Nigeria

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ABSTRACT: Phototaxis is exhibited by phototrophic organisms such as insects. They move toward the light source to take advantage of the energy necessary for photosynthesis. This paper aims to investigate phototactic insects: seasonal abundance and diversity in built environments in Awka, Anambra State, Nigeria using appropriate standard techniques. The result showed that a total of 1,587 insects belonging to sixteen insect orders were found to be phototactic in built environments. The highest number of insects was collected in site B (44.87%). The result shows that Diptera (42.66%), Hemiptera (24.26%), and Coleoptera (13.11%) had the highest relative abundance. The order Coleoptera was the most diverse group with 12 families and 19 species. The highest mean number of insects was recorded in the wet season (27.87±14.425%) compared to the dry season (6.02±3.226). Most notably, the abundance of phototactic insects collected in built environments Awka was higher during the wet season across all three sites. The correlation analysis revealed that there was no significant positive relationship between ambient temperature, relative humidity, and the abundance of phototactic insects during both the wet (ambient temperature, ($r = 0.29$, $P > 0.05$; $r = 0.586$, $P > 0.05$) and dry seasons ($r = 0.557$, $P > 0.05$; $r = 0.612$, $P > 0.05$)). The study revealed a significant difference in the abundance of phototactic insect species among the three sites in Awka. The wet season recorded a higher abundance of insects compared to the dry season. Despite seasonal fluctuations in mean temperature and relative humidity, these environmental variables do not appear to have a deterministic influence on the abundance of phototactic insects in the studied locations.

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Insects associated with the built environment have the potential to affect human well-being in multiple ways. Some insect species can cause structural damage to buildings, leading to financial losses for homeowners and building owners (New, 2015). Wood-boring beetles, termites, and carpenter ants, for example, are known to weaken wooden structures, compromising their integrity, and requiring costly repairs (Ciesla, 2011). According to Yalcin *et al.* (2021) and Kalleshwaraswamy *et al.* (2022); wood-destroying insects can cause significant economic losses globally. These insect pests are capable of tunnelling through wood, causing severe damage and compromising the structural stability of buildings. Additionally, certain insects can trigger allergies and asthma in sensitive individuals through their presence and the release of allergenic compounds (Matthysse, 2014). Allergies and asthma are widespread health issues worldwide, and indoor allergens, including those produced by insects, can exacerbate symptoms (Matthysse, 2014).

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For example, dust mites and cockroaches are common indoor allergens that can trigger allergic reactions and asthma attacks in susceptible individuals. Identifying the presence and abundance of allergenic insect species in buildings can help inform strategies to reduce allergen exposure and improve indoor air quality (Patel and Meher, 2016). The ongoing process of urbanisation and infrastructural development in cities like Awka, Anambra State in Nigeria, has led to significant changes in the local environment, particularly the proliferation of buildings and the alteration of natural habitats (Adefolalu *et al*., 2020). Awka, as the capital city of Anambra State, is experiencing rapid urban growth characterised by residential, commercial, and industrial building construction (Onuigbo *et al*., 2018). This urban expansion results in the creation of new habitats within the built environment, providing opportunities for various organisms, including insects, to colonise these structures (Chunwate *et al*., 2019).

Research conducted in other urban areas has highlighted the importance of studying insect communities within the built environment. Bertone *et al*. (2016) characterised the diversity of arthropods inside urban and suburban homes using light traps, demonstrating the efficacy of this approach in capturing and studying the insect fauna associated with built environments. Such studies provide valuable insights into the composition and diversity of insect communities, as well as their interactions with the built environment (Okeke *et al*., 2019). To effectively manage urban ecosystems and mitigate potential risks associated with insects in buildings, it is essential to fill the knowledge gap regarding insect species composition, abundance, and diversity in Awka. By deploying light traps in buildings across different areas of the city, researchers can gain valuable insights into the insect communities associated with these structures. This information can inform pest management strategies, urban planning practices, and the conservation of insect biodiversity in Awka and similar urban environments. Light traps have shown to be highly effective and valuable tools for monitoring and collecting insects in various ecological settings, including buildings and the built environment (Bertone *et al*., 2016). These traps take advantage of the positive phototactic behaviour exhibited by many insect species, which causes them to be attracted to light sources. When deployed in buildings, light traps provide a reliable means of sampling and studying the insect communities associated with these structures. A study by Laumann *et al*. (2018) for example utilised light traps to assess the diversity and abundance of stored-product pests in commercial buildings, providing valuable information for the development of integrated pest management strategies to control these pests in grain storage facilities. Therefore, the aim of this paper is to investigate the seasonal abundance and diversity of phototactic insects in buildings in Awka, Anambra State, Nigeria.

MATERIALS AND METHODS

Study Area: The present study was conducted in a built environment in Awka, Anambra State. Awka lies on the coordinates 6˚ 12N and 7˚ 04 E Anambra State (Akunne *et al*., 2019). Based on Location, Anambra State resides in the southeastern geopolitical region of Nigeria. Awka is the capital of Anambra State of Nigeria and is located in the lowland rain forest zone of southern Nigeria with an annual rainfall of 750 mm-1,200 mm that lasts for seven months (April – October), with two seasons; the dry and the wet season. The University is 65km from Enugu and 55km from Onitsha. The spatial size of the University is approximately 4.99km^2 (499 ha) between latitude 6° 14' 54" N and longitude 7° 6' 55" E with a bearing of 64.4° (ENE). The temperature in the study area is 27-30^{o}C between June and December, however, it rises to 32-34^{o}C between January and April, with March experiencing the hottest temperature at 36-38^{o}C. The relative humidity in the rainy season is 82.37 and 74.25 in the dry season (Hudson Institute of Mineralogy, 2019).

Description of The Study Site: A systematic random sampling method was employed to select the study sites. Various built environments, such as residential areas, commercial centers, and educational buildings, were considered. The sites were chosen based on their accessibility and the potential presence of diverse insect communities. This study was carried out in three sites named A, B, and C. The study site was three built environments located within Nnamdi Azikiwe University. Site A was in the Agbani area of second market, Ifite. Site B is located at the Faculty of Arts close to admin and banks Site C is located at Amansea. The study sites are all located within latitude 7˚01′55.4″E and longitude 6˚54′46.3″N. The locations were recorded using a portable global positioning system / GPS (GARMIN-etrex SUMMIT), starting from September 2023 to January 2024 (Fig. 1).

Procurement of Materials: Specimen bottles, lights, tweezers, and Camel's fine brush were purchased at Kevon Medical Store Amaenyi Awka. Plastic containers used for the light trap were obtained from a local store in the Eke-Awka market, Anambra State, Nigeria.

Experimental Design: For this study, a One-Shot Case Study design is employed. This straightforward design involves a single group exposed to the treatment, with outcomes measured directly (Bosse *et al*., 2014). Various kinds of light traps have been developed and utilised by researchers over time (Price and Baker, 2016). For this experiment, the funnel-type light trap was employed, constructed locally using wooden materials. Each side of the trap was 1 meter in height, featuring rounded hollow edges. A rechargeable Lontor torch lamp was suspended across the wooden frame within the trap. Throughout the entire study period, the torch lamp was activated every night. To facilitate the collection of insects, the hollow entrances on both sides of the traps were extended by using small rods that lead into collecting troughs. These troughs will contain a measured quantity of water and detergent, creating an effective insect capture solution (Shimoda and Honda, 2013). Additionally, to prevent insects from escaping and to enhance the efficiency of the traps, metal nets were wrapped around them along with the collecting troughs (Frost, 1957). This setup will ensure that captured insects remain confined within the trap for subsequent analysis and observation.

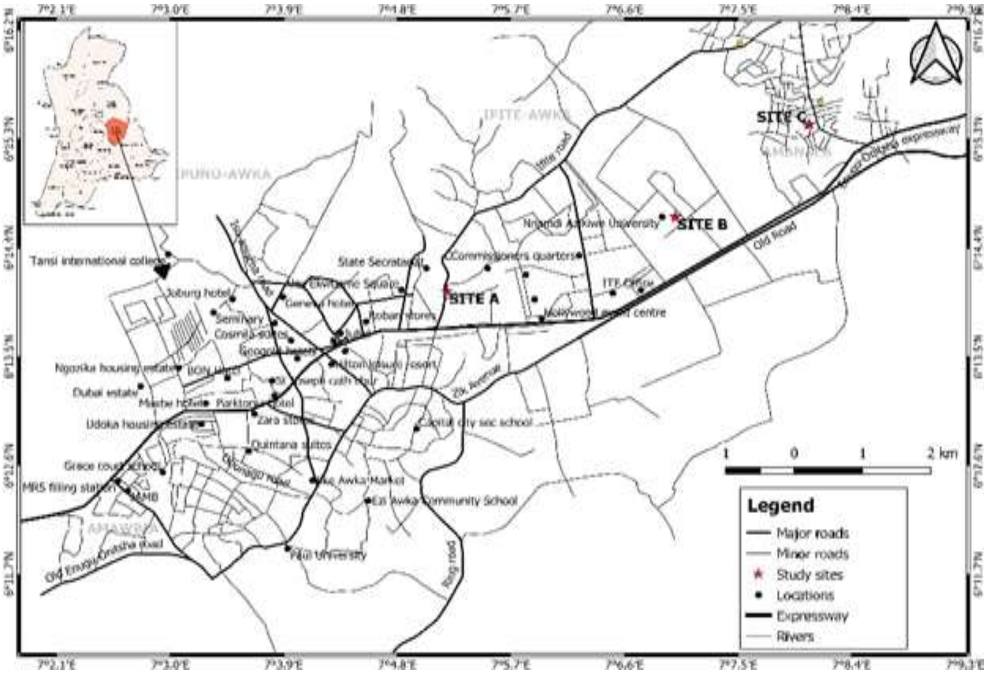

Fig. 1: Map of the study area showing the three sites; A, B, and C in Awka, Anambra State
Source: Researcher's fieldwork and GIS Mapping, 2024; Cartography by Department of Geography)

Sampling and Collection of Insects in the Study Area: The diversity of insect species associated with light traps was determined by the collection of the insects. The collection of insects took place from September to January 2024. The light traps were activated and positioned at the selected study sites each evening. The insects were collected two times daily and the trap was inspected every morning. The collection was done for 10 weeks and the insects caught were transferred into the specimen bottles. The insects were sorted into their respective species and preserved with 80% ethanol. After sorting of insects, they were preserved, packaged, and sent for identification.

Insect Sorting: Insects were sorted according to the method of Ewuim (2008), using Carmel's hair brush under a light microscope sorting of the insects was done. The insects were placed iinside specimen bottles containing 80% ethanol as a preservative.

Insect Identification and Preservation of Insects: These insects sorted into their taxonomic groups were carefully recorded in data sheets at the Insect Museum at Ahmadu Bello University, Zaria, Kaduna State, Nigeria for verification and identification of the insects. The voucher insects identified were placed in labeled vials that contained 80% ethanol for preservation as proper documentation was written down on dates, locations, and type of specimen collected. The specimen was properly kept for further studies and reference purposes.

Measurement of microenvironmental variables: The method employed to ascertain the average temperature and relative humidity, a key factor in understanding moisture availability and environmental conditions of the study site involved the use of a specialised digital HTC-2 thermohygrometer. Also, these parameters reading was taken at 4 times per month in the study area in the morning hours (8am – 9am) and in the evening hours (4 pm-5 pm).

Statistical Analysis: The data was collected and recorded in Microsoft Excel (version 2019). Species diversity, richness, and abundance were calculated to assess the insect community composition in the built environment of Awka. Shannon-Wiener index was performed to evaluate the diversity and distribution patterns of the insects (Magurran, 2004) using Microsoft Excel. Also, a non-parametric statistical test (Kruskal Wallis Test and Wilcoxon signed ranked test) was employed to examine significant differences in insect communities between various built environment types with Statistical Package for Social Sciences (SPSS) version 25.

RESULTS AND DISCUSSION

Population of Phototactic Insects in Built Environment in Awka: The population of insects that are phototactic in built environments in Awka were represented in Table 1. A total of 1,587 insects belonging to sixteen (16) insect orders were found to be phototactic in built environments in Awka. Out of this number, 417 (26.28%) were collected from site A, 458 (28.86%) were collected from site B and 712 (44.87%) were associated with site C. Hence, the highest number of insects were collected in site C. The insect orders collected were Coleoptera, Dermaptera, Dictyoptera, Diptera, Ephemeroptera, Hemiptera, Homoptera, Hymenoptera, Isoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Plecoptera, Trichoptera and Zygoptera. The result further showed that Diptera (42.66%), Hemiptera (24.26%), and Coleoptera (13.11%), had the highest relative abundance while Zygoptera (0.06%) had the least abundance. However, Diptera (76.02%), Hemiptera (38.37%), and Coleoptera (21.1%) recorded the highest relative abundance in site C compared to Site A (Diptera (47.96%), Hemiptera (28.3%) Coleoptera (14.39%) and site B, (Diptera (38.37%), Hemiptera (25.66%) Coleoptera (14.39%) respectively). There was a significant difference in the abundance of insect species that are phototactic among the sites in Awka (p =0.01).

Seasonal Abundance of Phototactic Insect Species Collected Using Light Traps in Built Environments in Awka: The results of the seasonal abundance of insects collected using light traps in built environments in Awka during the study period are presented in Table 2. The result revealed that the highest mean number of insects was recorded in the wet season (27.87±14.425) compared to the dry season which recorded 6.02±3.226. However, there was a significant difference in the total number of insects collected using light traps in built environments in Awka during wet and dry seasons at ($P< 0.05$).

The Margalef Index (D), Simpson dominance Index (C), Shannon Weiner Diversity Evenness (H), Shannon Weiner Diversity (E) of Phototactic Insects in Built Environments in Awka: The results on diversity and richness of insects that are phototactic in built environments in Awka are presented in Table 3 which shows that the Shannon Weiner Diversity index was highest in site B (3.071), followed by site C (3.044) while the least was recorded in site A (2.96). the Simpson's Index of Dominance was highest at site A (0.1140), followed by site C (0.1079), while the least was recorded in site B (0.083). Margalef Index was highest in Site C (6.829), followed by Site A (6.173) whereas Site B recorded the lowest (5.881). The Evenness recorded highest in site B (0.055) followed by site A (0.050), and site C (0.033).

Table 1: Population of Phototactic Insect Orders in Built Environment in Awka

Order	SA	RA (%)	SB	RA (%)	SC	RA (%)	Total (%)
Coleoptera	60	14.39	60	14.39	88	21.1	208(13.11)
Dermaptera	5	1.2	10	2.4	12	2.88	27(1.7)
Dictyoptera	8	1.92	3	0.72	9	2.16	20(1.26)
Diptera	200	47.96	160	38.37	317	76.02	677(42.66)
Ephemeroptera	7	1.68	7	1.68	8	1.92	22(1.39)
Hemiptera	118	28.3	107	25.66	160	38.37	385(24.26)
Homoptera	1	0.24	2	0.48	0	0	3(0.19)
Hymenoptera	14	3.36	35	8.39	52	12.47	101(6.36)
Isoptera	1	0.24	2	0.48	6	1.44	9(0.57)
Lepidoptera	8	1.92	10	2.4	19	4.56	37(2.33)
Neuroptera	1	0.24	0	0	1	0.24	2(0.13)
Odonata	0	0	1	0.24	1	0.24	2(0.13)
Orthoptera	22	5.28	12	2.88	25	5.99	59(3.72)
Plecoptera	8	1.92	4	0.96	9	2.16	21(1.32)
Trichoptera	5	1.2	3	0.72	5	1.2	13(0.82)
Zygoptera	0	0	1	0.24	0	0	1(0.06)
Total	**458**	**28.86**	**417**	**26.28**	**712**	**44.87**	**1,587(100)**

Keys: SA = Site A; SB = Site B; SC = Site C

Table 2: Seasonal Abundance of Phototactic Insect Species Collected Using Light Traps in Built Environments in Awka

Order	WS	RA	DS	RA	Total catches	RA
Coleoptera	177	13.5	32	11.31	209	13.12
Dermaptera	27	2.06	0	0	27	1.69
Dictyoptera	16	1.22	4	1.41	20	1.26
Diptera	633	48.34	44	15.55	677	42.51
Ephemeroptera	22	1.67	0	0	22	1.39
Hemiptera	230	17.57	157	55.47	387	24.31
Homoptera	3	0.23	0	0	3	0.19
Hymenoptera	91	6.95	13	4.59	104	6.53
Isoptera	9	0.69	0	0	9	0.56
Lepidoptera	36	2.74	1	0.35	37	2.34
Neuroptera	2	0.15	0	0	2	0.13
Odonata	2	0.15	0	0	2	0.13
Orthoptera	28	2.12	31	10.95	59	3.71
Plecoptera	20	1.53	1	0.35	21	1.32
Trichoptera	13	0.99	0	0	13	0.82
Zygoptera	1	0.08	0	0	1	0.06
Total	**1310**	**100**	**283**	**100**	**1593**	**100**
Mean abundance ±SEM	**27.87±14.425**		**6.02±3.226**		**33.89±17.651**	
Probability value	**P =0.00**					

Table 3: The Margalef Index, Simpson dominance Index, Shannon Weiner Diversity Evenness, Shannon Weiner Diversity of Phototactic Insects in built environments in Awka

Index	Site A	Site B	Site C
Shannon-Wiener Diversity Index	2.96	3.071	3.044
Simpson's Index of Dominance	0.1140	0.083	0.1079
Margalef Index	6.173	5.881	6.829
Evenness	0.050	0.055	0.033

Seasonal Mean Temperature (°C), Relative Humidity (%), and Abundance of Phototactic Insects that are in built environments in Awka: The summary of the result on the mean seasonal environmental variables (temperature and relative humidity) was presented in Table 4. The result showed that the highest mean temperature in site A was recorded in the Dry season (28 ºC ±7.248) while the least was in the wet season (25.33 ºC ±2.55). However, there was no significant difference in the mean seasonal relative humidity in the study sites. The relative humidity in site A was higher in the Wet season (81.78%±19.185) and least in the Dry season (53.67±9.661). However, there was a significant difference in the mean seasonal relative humidity in the study sites. The result revealed that the highest mean seasonal temperature in site B was recorded in the dry season (27.89±6.599) while the least was recorded in the wet season (19.75±2.55). However, there was no significant difference in the mean seasonal relative humidity in the study sites. The relative humidity in site B was higher in the Wet season (81.78±19.185) compared to the dry season (53.67±9.661). However, there was a significant difference in the mean seasonal relative humidity in the study sites. The result revealed that the highest mean seasonal temperature in site C was recorded in the dry season (26.67±6.94) while the least was recorded in the wet season (25.78±3.1). However, there was no significant difference in the mean seasonal relative humidity in the study sites. The relative humidity in site B was higher in the wet season (83.22±16.16185) compared to the dry season (50.55±18.04). However, there was a significant difference in the mean seasonal relative humidity in the study sites. Furthermore, the result in Table 4 further revealed that the highest mean number of insects that are phototactic in built environments in Awka in the three sites was highest in the wet season compared to the dry season. However, there was a significant difference in the mean seasonal relative humidity in the study sites.

Table 4: Seasonal Mean Temperature (°C), Relative humidity (%), and abundance of phototactic insects in built environments in Awka

Microclimate variables	Season	Site A	Site B	Site C	Insect Abundance	P value
Temperature C	Wet season	25.33±2.55	19.75±2.55	25.78±3.1	27.87±14.425	0.187
	Dry Season	28±7.248	27.89±6.599	26.67±6.94	6.02±3.226	
Humidity	Wet season	81.78±19.185	81.89±16.226	83.22±16.16	27.87±14.425	0.00
	Dry Season	53.67±9.661	50±16.357	50.55±18.04	6.02±3.226	

Relationship between Temperature, Relative Humidity, and Abundance of Phototactic Insects built environments in Awka during the Wet Season: The result of the relationship between the number of insects that are phototactic in built environments in Awka and environmental variables (temperature and relative humidity) during the wet season is presented in Table 5. The correlation analysis showed that there was no significant positive relationship between the number of insects that are phototactic in built environments in Awka during the wet season, and the ambient temperature (r = 0.29, P> 0.05). Similarly, there was no significant positive relationship between the abundance of insects that are positively phototactic in built environments in Awka and the relative humidity (r = 0.586, P> 0.05) during the wet season.

Table 5: Relationship between temperature, relative humidity, and abundance of phototactic insects in built environments in Awka during the wet season

		Insect Abundance	Temperature	Humidity
Insect Abundance	Pearson Correlation	1		
	Sig. (2-tailed)			
Temperature	Pearson Correlation	0.29	1	
	Sig. (2-tailed)	0.71		
Humidity	Pearson Correlation	0.586	-0.603	1
	Sig. (2-tailed)	0.414	0.397	

Relationship between Temperature, Relative Humidity, and Abundance of Phototactic Insects built environments in Awka during the Dry Season: The relationship between the number of insects that are phototactic in built environments in Awka and environmental variables (temperature and relative humidity) during the dry season is presented in Table 6. The correlation analysis showed that there was no significant positive relationship between the number of insects that are phototactic in built environments in Awka during the dry season, and the ambient temperature (r = 0.557, P > 0.05). Similarly, there was no significant positive relationship between the abundance of insects that are phototactic in built environments in Awka during the dry season and the relative humidity (r = 0.612, P> 0.05).

Table 6: Relationship between temperature, relative humidity, and abundance of phototactic insects that are in built environments in Awka during the wet season

		Insect Abundance	Temperature	Humidity
Insect Abundance	Pearson Correlation	1		
	Sig. (2-tailed)			
Temperature	Pearson Correlation	0.557	1	
	Sig. (2-tailed)	0.443		
Humidity	Pearson Correlation	0.612	.998**	1
	Sig. (2-tailed)	0.388	0.002	

** Correlation is significant at the 0.01 level (2-tailed).

Phototactic insects are attracted to light, a behaviour that has been documented widely across various insect taxa (Park and Lee, 2017; Donners 2018; Kim *et al*., 2019). The results from this study on phototactic responses among insects within built environments in Awka showed a varied attraction of certain insect orders to artificial light sources. The findings align with the growing body of research that demonstrates a range of phototactic behaviours in nocturnal and diurnal insects (Perkin *et al*., 2014; Owens *et al*., 2020 Wang *et al*., 2023). Site C has the highest number of phototactic insects which suggests the presence of more attractive light sources or environmental conditions conducive to these insects.

This is in line with the study by Owens and Lewis, (2018), who highlighted that specific characteristic of light, such as intensity and wavelength, could significantly influence insect attraction. The predominance of orders such as Diptera, Hemiptera, and Coleoptera is consistent with the study of Sia *et al.* (2017) who noted that many Dipterans exhibit strong phototaxis, congruent with the highest relative abundance of this order found in our study. Remarkably, the relative abundance of these orders varied across the three locations, with site C displaying a markedly higher abundance of Diptera and Hemiptera. This differential distribution underpins findings by (Frank, 2015), who reported that local environmental conditions, including light pollution levels, can considerably impact the diversity and abundance of phototactic insects within urban areas.

The lesser abundance of Zygoptera, Neuroptera, and Odonata, which represented the smallest proportion of phototactic insects, correlates with studies that suggest these orders are not as strongly attracted to artificial lights as others (Frank, 2015; van Grunsven *et al*., 2014; Frank, 2006). Variables such as flight activity period and feeding behaviour can influence the level of attraction to light sources, which could explain the low numbers of these orders observed in the current study. The significant difference in the populations of phototactic insects across the different sites reaffirms that the built environment and its associated light pollution are factors influencing insect behaviour and distribution (Horváth *et al*., 2009). Such evidence supports the report that urbanisation and the subsequent installation of artificial lighting profoundly impact the ecology of nocturnal insects (Falchi *et al*., 2011).

The findings of the study from insects collected with light traps in various built environments across Awka demonstrate significant variations in insect abundance and diversity, which align with many findings within entomological research. The high abundance and diversity of coleopterans in the sampled environment are consistent with other studies that identify coleoptera as one of the most diverse insect orders globally (Hunt *et al*., 2007). The presence of Coleoptera indicates a varied habitat preference and potential adaptability to the built environment within this group. In comparison, Diptera also shows a substantial presence, which is supported by findings by Hakami *et al*. (2020) who suggest that Diptera is a common urban inhabitant due to their attraction to artificial lighting and various microhabitats in human-modified areas.

Similarly, Hemiptera, with 9 families and 17 species, aligns with the findings of Schuh and Slater (1995) on their considerable adaptability to different environmental conditions, including urban settings. The relative abundance of *Culicoides sonorensis* and *Culex fatigans* in sites A and C, and site B respectively, raises concerns about potential vector-borne diseases, a common theme in urban entomology studies (Brown and Stinson, 1996). The low abundance of certain species across the sites could suggest specific environmental or ecological factors limiting their distribution, or possibly the selectiveness of light traps for particular insect taxa (Southwood and Henderson, 2000).

The significant seasonal variation in insect abundance observed in the present study aligns with established patterns in entomological research, which denote that climate and weather conditions markedly influence insect activity and population dynamics (Field *et al*., 2014; Saunders, 2020). In particular, the increased mean number of insects captured during the wet season can be attributed to the higher humidity and temperatures, conditions known to be conducive for insect proliferation and increased activity (Stork, 2018).

This is especially pertinent to the fact that light traps have a higher attraction efficiency under such environmental conditions (Svensson *et al*., 2004). The significant difference between the wet and dry season highlights the effect of seasonality on insect behaviour in built environments, particularly regarding their responses to artificial light sources. Previous studies have reported that insects are more attracted to light traps during periods of higher humidity which is consistent with the findings in Awka (Rydell, 1992; Eisenbeis, 2006). In contrast, the dry season exhibited a reduced mean number of captures, which is likely a consequence of the decreased humidity and cooler temperatures that lead to reduced insect metabolic and movement activities (Yihdego *et al*., 2019; Evans *et al*., 2009). Furthermore, the present study showed that increased insect activity around light traps in the wet season may reflect not only intrinsic physiological cycles of the insects involved but also the availability of resources and mating opportunities, which are generally heightened in more favourable climatic conditions (Stork, 2018). This aligns with the findings of Horváth *et al*. (2009), who noted that artificial lights could disrupt the nocturnal activities of insects, particularly in their natural habitats, potentially translating to altered patterns in an urban setting.

Site B in the study exhibited the highest Shannon Weiner Diversity Index, implying a more diverse insect community relative to other sites. High diversity is often a result of various environmental niches or light conditions promoting a diversity of species (Southwood and Henderson, 2000). Site B also had the lowest Simpson's Index of Dominance, indicating no single insect species was overwhelmingly dominant, unlike Site A, which showed signs of a less equitable insect population possibly due to specific species benefiting from the light conditions excessively. Margalef Index values demonstrated the greatest species richness at Site C, followed by Site A, and the least at Site B. Species richness, a measure unrelated to diversity, simply counts the different species present and may reflect a range of microhabitats or lighting conditions attracting different insects (Margalef, 1958; Pauleit *et al*., 2019).

The Shannon Weiner Evenness Index revealed the most evenly distributed species at Site B and the least evenness at Site C, suggesting a potential imbalance caused by certain species favored by specific lighting. Evenness contributes to ecological resilience by spreading risk and reliance among many species, which is especially important in the context of urban lighting (Jost, 2006).

The study also cites the influence of artificial light on insects, with documented impacts on community structure, mortality rates, and behaviours, and variations in insect attraction to different light wavelengths (Longcore and Rich, 2004; Owens and Lewis, 2018). Additionally, the research investigated environmental factors' seasonal impacts, such as the influence of temperature and relative humidity on the presence of positively phototactic insects in urban built environments in Awka. Seasonal temperature changes were observed, with the highest mean temperature at Site A during the dry season, reducing in the wet season, a trend also seen at Sites B and C. Despite temperature shifts, changes in relative humidity were not statistically significant between sites, though a general humidity increase during the wet season was acknowledged (Bebber *et al*., 2013). A key finding was the heightened presence of light-attracted insects indoors during the wet season, posited to result from the interplay between environmental factors and artificial building lighting (Eisenbeis and Eick, 2010; Longcore and Rich, 2004).

The notable seasonal pattern in positively phototactic insect abundance may be influenced by both thermoregulation motives and the avoidance of outdoor conditions that are less conducive to their survival or activity patterns. It is reported that light, temperature, and humidity significantly influence the activity levels and distribution of insect populations (Rich and Longcore, 2006). The precarious outdoor conditions during the wet season, with higher precipitation and humidity, might underlie the increased migration of these insects into buildings, where they seek refuge and more stable environmental conditions (Koehler *et al*., 1995; Field, *et al*., 2014). This can be more pronounced in urban areas due to the heat island effect which is combined with the lit environments (Wang *et al*., 2019).

Furthermore, the result that the abundance of positively phototactic insects is greater in the wet season suggests that light pollution inside buildings compared to the darkness and moisture conditions outdoors creates an attractant effect for these insects (Eisenbeis, 2006). Studies have shown that artificial lighting can disrupt the natural behaviours of nocturnal insects and attract them to indoor areas (Hölker *et al*., 2010). This could potentially increase human-insect interactions and may have implications for pest management and public health due to the possibility of disease vectors (Donnelly *et al*., 2001; Owens and Lewis, 2018).

The findings from the current study adhere to the patterns observed in other research within the field of urban entomology. For instance, the work by Meyer and Sullivan (2013) indicated an increase in urban insect abundance with corresponding peaks in artificial light intensity and humidity, aligns with the results of the study. Nonetheless, although light and humidity factors maintain a significant role in insect behaviour, other underlying environmental, and anthropogenic factors could also modulate these observed patterns (Bennie *et al*., 2016).

This study investigated the relationship between temperature, relative humidity, and the abundance of phototactic insects in built environments in Awka during the wet and dry seasons. Findings indicate no significant correlation between phototactic insect numbers and either ambient temperature or relative humidity. This contrasts with Götz (2019), who noted that environmental factors like temperature and humidity significantly influence insect behaviours. The study's non-significant results could be due to the minimal effect of these factors in built environments (Horridge, 1965; Méndez *et al*., 2022). Additionally, the absence of a strong correlation suggests that other factors may be more influential in determining insect abundance, or the temperature and humidity ranges was not broad enough to detect their influence on insect behaviour.

This finding contradicts Chesson *et al*. (1997), who observed that nocturnal insect light attraction increased with warmer conditions (Méndez *et al*., 2022). Insect responses to light vary significantly among species, with some being more light-sensitive than others, influenced by complex interactions with environmental variables (Eggleton and Belshaw, 1992). The insect community in Awka may consist of species with different temperature and humidity thresholds, affecting their phototactic behaviour and potentially diluting any correlation in a mixed-community analysis (Méndez *et al*., 2022). Additionally, phototactic behaviour might not solely depend on these factors; the intensity and wavelength of light sources could play a more significant role in insect abundance than climatic conditions (van Langevelde *et al*., 2011).

Results showed no significant influence of these factors, diverging from previous studies and suggesting more complex interactions between environmental factors and insect behaviour (Stock, 2018). The moderate correlation coefficient indicating a non-significant positive relationship between temperature and insect abundance contradicts earlier studies, which found that warmer temperatures heighten insect attraction to light, aligning with increased metabolic rates and activity levels (Stern and Horváth, 2018; Horváth *et al*., 2009; Robertson, 2009).

Similarly, the non-significant relationship between relative humidity and phototactic insect abundance does not align with findings by Méndez *et al*. (2022), who noted increased insect activity and light attraction under higher humidity conditions. The discrepancy in results may be due to the specific demographics of insects during the dry season, where humidity impacts might be less pronounced or moderated by other environmental factors. These differences could also be attributed to the behavioural ecology of local insect fauna, which may have unique adaptations or preferences. The influence of artificial light sources in built environments might significantly impact insect behaviour more than natural temperature and humidity fluctuations (Eisenbeis, 2006). Additionally, other factors such as wind speed, air pressure, or architectural features of buildings might affect insect behaviour (Longcore and Rich, 2004).

Conclusion: This research contributes to existing scientific knowledge by providing insights on how urbanisation and artificial lighting affect insect distribution in built environments. The study highlights that insect abundance and diversity in Awka, Anambra State, are influenced by varying light characteristics and environmental conditions. The findings reveal that certain insect orders, such as Coleoptera, Diptera, and Hemiptera, exhibit strong phototactic behaviour, while others like Zygoptera, Neuroptera, and Odonata are less attracted to light. Seasonal variations in insect capture rates were observed, with higher rates during the wet season, indicating favourable conditions for insect activity. The study highlights the relationship between environmental factors and insect distribution. Hence, this provides a foundation for further urban entomology and ecology research.

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Data Availability Statement: Data are available upon request from the first author or corresponding author.

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